Assessing the Security of Buildings: A Virtual Studio Solution

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ABSTRACT

This paper presents an innovative IT solution, a virtual studio, enabling security professionals to formulate, test and adjust security measures to enhance the security of critical buildings. The concept is to *virtualize* the environment, enabling experts to examine and assess and improve on a building's security in a cost-effective and risk-free way. Our virtual studio solution makes use of the latest advances in computer graphics to reconstruct accurate blueprints as well as 3D representations of entire buildings in a very short timeframe. In addition, our solution enables the creation and simulation of multiple threat situations, allowing users to assess security procedures and various responses. Furthermore, we present a novel device, tailored to support collaborative security planning needs. Security experts from various disciplines evaluated our virtual studio solution, and their analysis is presented in this paper.

Keywords

3D representation of buildings, security assessment, indoor reconstruction, collaborative environment, mission planning

INTRODUCTION: SECURING CRITICAL BUILDINGS

The characteristics of large cities, with their complex geospatial environment, traffic congestion, large numbers of inhabitants and tourists, visiting dignitaries, various events and population mixes, have made evolving threats difficult to anticipate. In light of the complexity and increased vulnerabilities that urban environments pose, designing the security of government buildings and other critical infrastructure sites has become extremely challenging for administrators and security professionals. Therefore, it is essential for security strategists to better plan and train organizations and crisis managers and to provide relevant systems for complex crisis management across organizational and geographic boundaries.

To secure a government building against multiple and evolving threats while maintaining a minimal level of transparency and accessibility requires an integral security approach, one that fosters interdisciplinary collaboration between security experts. The development of a security and emergency preparedness management plan requires partnerships between various government agencies, regional/local authorities, government owned corporations, non-government organizations and public utility network providers. These partnerships should recognize the need for a collaborative approach to ensure effective coordination of planning, transfer of information and provision of resources necessary for a comprehensive and effective plan.

But security experts suffer from the absence of common knowledge with regard to the most effective measures and practices to protect critical buildings. They often speak different "languages" depending on the particular aspects of the buildings they are in charge to protect. As a result, the challenge of securing critical buildings is hard to meet (Boin, Hart, Stern, Sundelius, 2005; Lu, 2014; Turner, 1978).

One obvious problem is that many threats which may materialize in or near critical buildings are hard, if not impossible, to simulate using just one's imagination, some paper and a pencil. Existing tools do not allow for the effective creation, analysis, assessment, and sharing of security concepts that can help administrators provide a secure environment for personnel and citizens. In this paper, we argue that virtual reality can lift this major constraint in collaborative planning and threat assessment.

This paper presents an innovative IT solution which aims to enable security professionals and administrators to jointly formulate, test, and adjust security concepts and measures in a virtual environment. Our solution provides a cost-effective and risk-free environment in which to devise an evidence-based, all-risk approach for the protection of critical buildings.

The design rationale for our solution is fourfold. First, we sought to create a virtual environment in which any building could be replicated, taking into account its urban environment. By allowing a 3D view of a critical building and its immediate environment, security professionals have a tool that fuels the imagination while keeping them grounded in reality. Second, we wanted this tool to facilitate joint cooperation across disciplinary boundaries in thinking about and planning for security. The tool should create a symbolic language that helps to bridge the conceptual boundaries that comes with professional training. Third, the tool should allow security professionals to manipulate the building and its environment, enabling them to capture the environment from multiple angles and discuss possible threats, which can be interactively inserted into the virtual environment. Fourth, the system should allow professionals to capture the situations they imagine or recreate from real situations. This allows them to revisit threats or compare plans for specific threats across time and space.

Our proposed solution makes use of the latest advances in the research field of interactive visualization and simulation. The solution enables to integrate GIS layers for the surroundings and we introduce a novel method to capture blueprints as well as generate 3D representations of entire buildings in a very short time frame, using mobile devices, which can be manually adjusted afterwards. The reconstructed and assembled environment serves as the bedrock for the simulation of multiple event and threat situations. These situations enable users to assess security procedures in response to threat situations by introducing virtual equipments, units and sensors. Moreover, our solution includes a novel device which has been designed to support multiple users to simultaneously share annotations on the current situation and favors discussions. Our proposed solution includes on-site capturing of the environment to easily bring it digital, where the later virtual exploitation in a risk-free and collaborative space fosters a Virtual Studio solution.

This paper is structured as follows: section 1 introduces existing security frameworks where our solution could be a benefit. Section 2 presents the capture and construction of the digital environment. Section 3 presents a security assessment tool, from visualization to simulation features. Section 4 presents the collaborative device and concludes on the performances of our solution, while section 5 highlights evaluation results of our proposition from experimentations conducted with security experts from various disciplines.

SECURITY OVERVIEW OF CRITICAL BUILDINGS

A network of public agencies is typically responsible for the security of public buildings including national departments, embassies, and critical infrastructures. But during the design of a building, the entities responsible for protection are often not involved. Security experts are mainly involved during the operational security phase of a facility during which they can influence the tactical security measures according to the facility type.

The security procedures governing the operational phase of a facility require regular assessment of security plans. As different groups have different and dynamic security needs, security plans of a facility should be reviewed on a monthly/quarterly basis by the governmental security task force. Most security plans are maintained in hard copies. A security plan usually captures the worst case and most probable scenarios. From our analysis of a number of European countries, we show in Table 1 the ranking for the threat assessment and threat grouping by source. The response level for addressing the threats varies according to the nature of the threat, where its ranking for public buildings is shaped by the security measures already in place, the possible degree of damage related to the population of the facility, the security personnel's awareness of the threat and potential damages, the available means for an adequate response and lastly, the importance of the asset.

Threat Assessment Ranking	**Threats categorised by source**
1. Protection measures	1. Terrorism
2. Site population/capacity, site accessibility, historic knowledge	2. Anarchism
3. Expertise to induce damage	3. Organised and common crime
4. Availability of means for causing (collateral) damage	4. Anti-social behaviour
5. Visibility and importance of assets	5. Demonstrations / public gatherings / strikes that turn violent
	6. Technological accidents
	7. infrastructure collapse
	8. Cyber incidents.

Table 1. Threat Assessment ranking and Risk Assessment source categorization

European security experts participating in government building security communicate with other European colleagues and cooperate to identify benchmark and mitigate risks. There are no legal obstacles obscuring the flow of knowledge sharing, and it is desirable to use common mock-up buildings and scenarios. The abovementioned features constitute the Emergency Preparedness Management Plan, depicted in Figure 1 below.

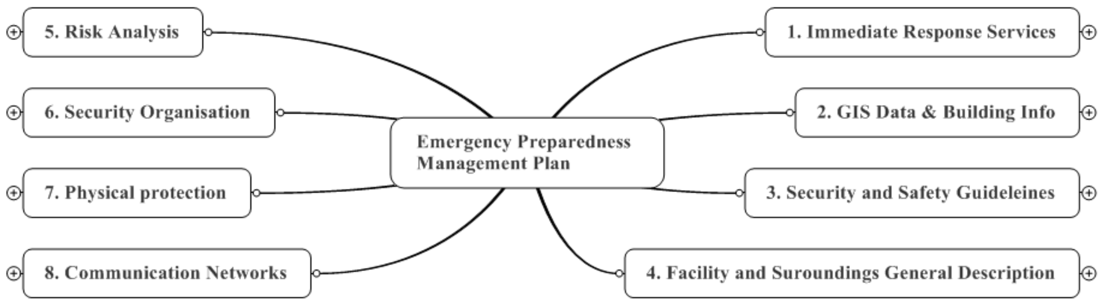

Figure 1. Emergency Preparedness Management Plan main components

The Emergency Preparedness Management Plan typically includes the following information:

1. the first responders who shall be involved and notification methods
2. the facility evacuation plans and assembly points, and blueprints identifying the main public utility network interconnection points
3. the security policies in place, the number of security personnel and their instruction and training level with respect to the response to a threat
4. information about the building's structural composition, the building materials, fire protection means, alarm sensors installed, information about the perimeter and the surroundings, power distribution diagrams, perimeter lighting, etc.
5. holistic risk analysis performed for the facility, if possible including cascading effects

6. the facility's security personnel organizational chart, and contact information
7. the security measures in entrance points, CCTV means and access to the facility's command and control center, restricted areas, access control scheme, surveillance points, etc.
8. standard operating procedures for parcel screening, the communication networks, any redundancy topology in place, backup and restore plans, a vulnerability study to cyber threats

The first four components highlight the need for security experts and decision makers to have a view on the building characteristics and surroundings, the response units available and the existing security measures. Our approach is to give experts the tools to assess existing security measures by creating a virtual representation of the facility and its surroundings. The following sections describe the novel tools we propose to reconstruct the environment, simulate situations and collaborate.

DIGITAL ENVIRONMENT CONSTRUCTION

Traditionally, creating a mock-up of a building was a difficult and time consuming task that architects and civil engineers had to tackle, as depicted in Figure 2. The creation of a building containing the necessary information to evaluate security plans could take several weeks. The tools introduced in this paper, which enable the interactive construction, visualization and manipulation of geographic environments, reduce these time-consuming tasks to less than a day.

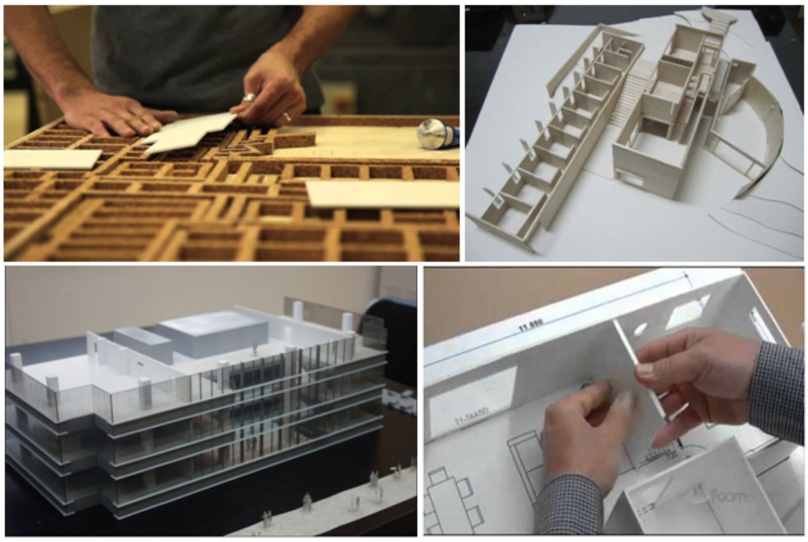

Figure 2. Manually constructing a building takes a considerable amount of time

Governmental buildings are often co-located in dense urban environments and implies that the security plan must include all critical assets in the immediate vicinity of the buildings. As a solution to the problem, we decided to make use of the VirtualGeo[1] technology, a 2D/3D Geographic Information System (GIS), to provide the visualization of the outdoor surroundings of the buildings. GIS technology is an easy and standard mean for users to import datasets, including free and reliable ones, to visualize the world in 2D and 3D maps, from a global to a local scale. This digital environment creation tool gives an easy yet powerful mean for security experts to visualize and thus take into consideration the surroundings of critical assets.

In many time-critical scenarios, fast capture of buildings is required. Although automated approaches exist for outdoor scenes, there is currently no effective solution for non-technical people to create models of indoor environments, which contain both enough geometric features to enable simulations and enough visual information to support location recognition.

The use of modern mobile devices to create a 3D map of an indoor environment is a growing and promising approach, as highlighted in the Tango project[2]. There is also a growing interest in semi-automatic methods that

[1] http://virtual-geo.com/en/

[2] https://www.google.com/atap/project-tango/

simplify the capture process, eliminating the manual post-processing necessary for reconstructing the layout of walls.

Semi-Automatic Indoor Acquisition

Our method for capturing the interior of a building requires as input omnidirectional images of interconnected rooms, acquired by a commodity mobile device, as depicted in Figure 3. With the height estimation function, the resulting structure is represented in real-world metric dimensions, without the need for any manual intervention. The reconstructed environment can be integrated as a digital representation of the facility in the virtual environment. The room shape is defined directly on the input images using the geometric model proposed in (Pintore and Gobetti, 2014).

The method described above can be iterated to map and reconstruct a multi-room structure with the aid of a minimal tracking of the user's movements through the mobile device inertial measurement unit, as highlighted in Figure 4 and (Pintore, Agus and Gobetti, 2014; Pintore, Garro, Ganovelli, Agus and Gobetti, 2016).

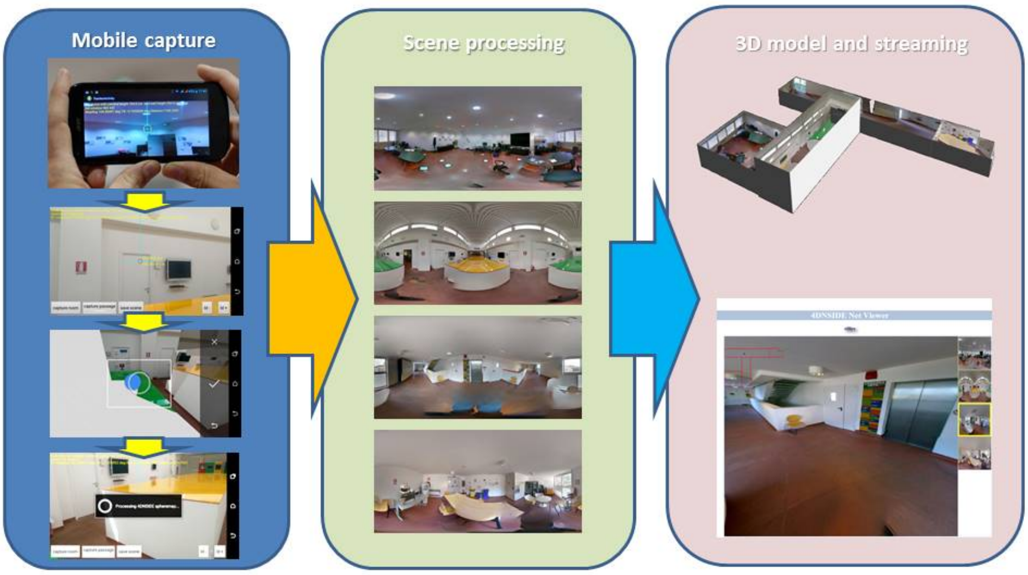

Figure 3. The indoor reconstruction system architecture

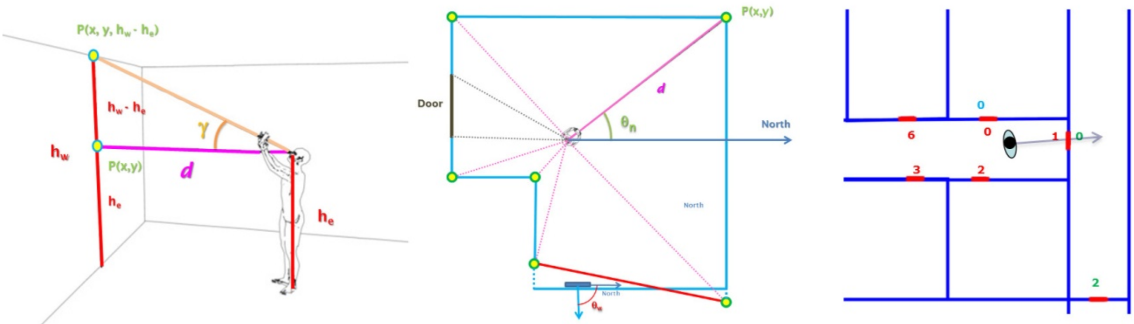

Figure 4. Left and center: single room geometric model; right: floor plan mapping model

Manual Construction and Adjustments

The reconstructed building is geo-positioned in the virtual environment during the acquisition process. However, this positioning information is approximate and we propose the means to manually adjust the building location as well as its dimensions. In addition, there is a need for the possibility to construct a digital representation of the building remotely, without having to go to the location of the facility in question. We therefore propose in our solution a manual 3D building creation tool.

To be effective, the construction tool must be highly reactive and provide real-time feedback. An indoor building editor based on 2D plans enables the user to quickly create floors and add outer and inner walls, doors and windows from a predefined database. Once a floor has been created, a user can duplicate it choosing which elements should be kept in the new floor. This ensures rapidity in completing the building plans. The 3D representation of the building is achieved procedurally, first through an extrusion algorithm of the walls, and second, through a geometrical cutting extraction method that enables the creation of holes to deposit pre-existing carpentry meshes, adapted to the size of the hole. The generated building is compliant with the interoperable Building Information Model (BIM) format becoming a standard in architectural constructions. This building creation tool is integrated in the GIS software, allowing a user to construct the building directly on the blueprints of the facility using, for example, Open Street Map[3], as depicted in Figure 5. This integration facilitates and speeds the process of creating the desired facility in a virtual environment.

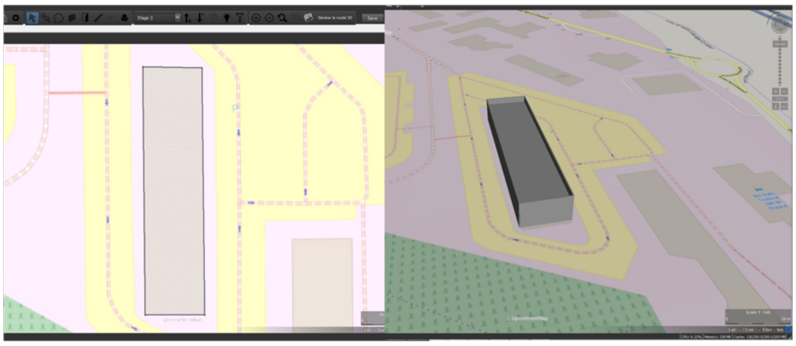

Figure 5. The building is directly created in the GIS environment. By using maps containing blueprints, the construction is facilitated and enables automatic geo-localization.

Furthermore, we propose a filter tool that allows users to focus on the desired building information. Through the BIM structure convention, the filter tool can activate/deactivate the corresponding node in the hierarchy of the building model. Figure 6 shows a reconstructed embassy with different configurations. The presented construction and filtering features are not limited to our examples and are applicable to many types of buildings. We already have constructed dozens of buildings for internal use, ranging from houses to government buildings. The indoor capture tool has some limitations with long and narrow corridors, an aspect that we will tackle in future work.

ASSESSMENT TOOLS

We also present in this paper items that can be added to the virtual environment and that will assist security professionals in evaluating, assessing and adapting a security concept. This feature includes the possibility to populate both the indoor and outdoor virtual environment with equipment, individuals, units, crowds, events and threats. This is done through the use of a simulation engine[4] where these virtual entities evolve in a world scale and dynamic environment. During our research study, a set of 300 virtual entities have been created. A virtual entity is composed of a 3D and a 2D visual representations, an equipment-specific behavior including its Human Machine Interface and meta-information to tag the equipment category for database indexing and searching. The entire database of virtual entities, ranging from police units to fire simulation and terrorist bombing will not be described in this paper, with the exception of equipments that are considered key.

A must-have feature required by security experts is the possibility to insert cameras into their security plans. Indeed these IT equipments enable security teams to monitor a facility and also to have an overview of the situation. We researched and developed a means to *virtualize* security cameras, with the appropriate controls and behaviors. The first feature is the possibility to visualize the coverage of a camera with an effective color-encoded visual feedback, which allows users to quickly identify the areas outside the cones of vision. Furthermore, we implemented a replica of a control centre, in a common "grid view" where all security cameras

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[3] https://www.openstreetmap.org/

[4] http://inscape.diginext.fr/

are streamed and controllable, as illustrated in Figure 7.

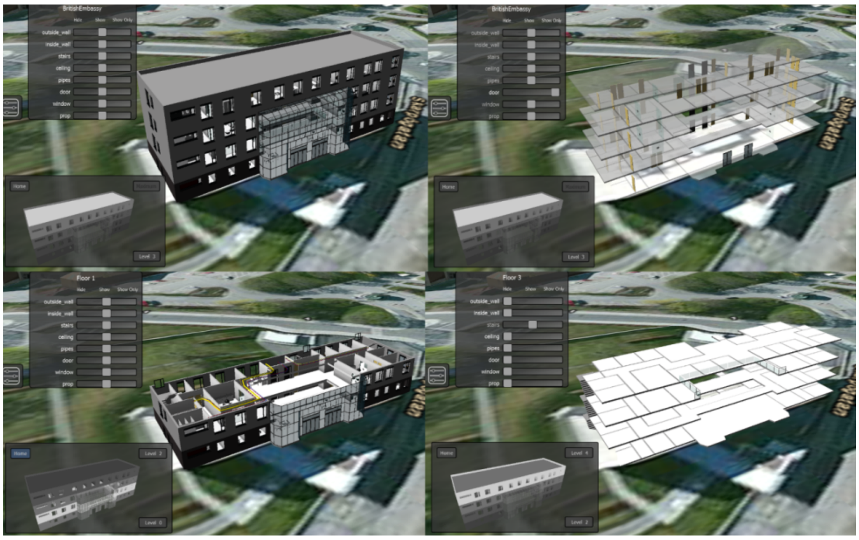

Figure 6. A user filters an embassy interior to focus on the desired information. Top left: the entire facility. Top right: only the floors and the access points – doors – are visible. Bottom left: the focus has been made on a specific floor. Bottom right: a multiple floor plan representation.

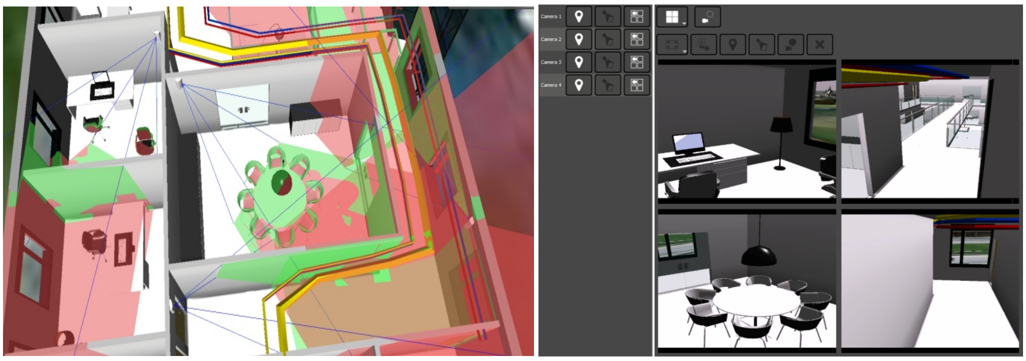

Figure 7. Left: The visibility coverage of multiple security cameras enables end-users to acknowledge the hidden zones. Right: The virtual "operational centre" offers the possibility to see through all the virtual cameras

Efforts have been made on the ergonomic of the user interface, to ease the creation of situations, using the drag-and-drop metaphor from a virtual entity database, and dedicated motion controls as illustrated in Figure 8. In Figure 9, a response plan to a fire in a critical building has been designed with our solution in a few seconds. Lastly, the security concepts and measures including virtual equipment, multiple threats, documents such as regulations or procedures, are all stored in a central repository share with collaborators and easily accessible. These stored results could be used for briefing or debriefing phases.

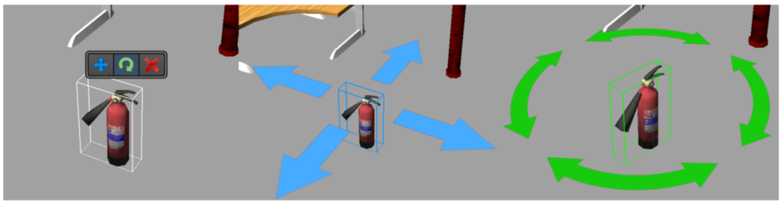

Figure 8. A fire extinguisher from the virtual equipment database is selected. A menu enables the user to move the object (blue arrows), to rotate the object (green arrows), and to remove it from the scenario

Figure 9. A response plan to a fire in a critical building, designed in seconds

COLLABORATIVE AND IMMERSIVE ENVIRONMENT

The software we propose can be enhanced with the help of dedicated hardware to foster discussions during the preparation of security plans. Improving Emergency Preparedness or Management Processes entails the analysis of the communication tools to improve human exchanges of information. Dedicated terminologies have been studied in detail for a long time (Reuter, Pipek, Wiedenhoefer and Ley, 2012), and the design of IT based platforms appears in several research programs (Benssam, Nouali-Taboudjemat and Nouali, 2013). In a decision-making context such as the preparation and the assessment of building security, we claim that the Computer-Human-Interaction, and more generally the organization of working area, plays a major role in improving the collaborative process. To that end, we propose a novel device that is not just a container of concepts but also an area cleverly engineered to support human interaction on a background of different skills, cultures and knowledge.

The analysis of user requirements preceding the design of the solution showed that such a tool should at least comply with demands of user friendliness and components interoperability, while having the ability to gather data from different information sources and to access data and systems through a single application. Intuitiveness, practicality and the capacity to share data among experts and connect with multiple disciplines are essential in such a multidisciplinary process. The collaborative solution relies on a clever mix of hardware and software, and aspires to meet these challenges by integrating a touch-screen and tangible objects as input interfaces designed to easily orchestrate a pool of heterogeneous data.

A Real Device for Real Meetings

Figure 10 illustrates a first prototype of the collaborative solution. This consists of a meeting table featuring all the ergonomic precautions required. The height of the table combined with specific tools provides comfortable conditions to respect sitting and standing positions. The mobile stand allows users to securely and quickly move the entire system from one room to another. The stand is suitable with a handicap access operator. The analysis of working processes demonstrate that users are switching regularly between brainstorming and conferencing sessions involving small and medium-sized groups. The stand is also motorized in order to easily switch the tabletop in a vertical position more suitable for a conferencing sessions with medium-sized groups.

In addition, this table is equipped with a touch-screen enabling users to put the information on the digital surface, in real time. Digital information is no longer just an input or an output support, but also a tool to engage in and facilitate the decision-making process. This choice bridges the gap between ICT experts and non-experts by reducing the learning curve. In addition, the integrated water-proof tabletop is also designed with multi-users capability (40 simultaneous touches). This makes a major difference regarding standard personal interface as mouse or keyboard by ensuring a simple enough system for everyone to take control of the information. The discussions can more easily be focused on the topic by making the technology seamless.

Figure 10. Integration of a horizontal device designing to replace the standard meeting table

Tangible Objects as Digital Tools

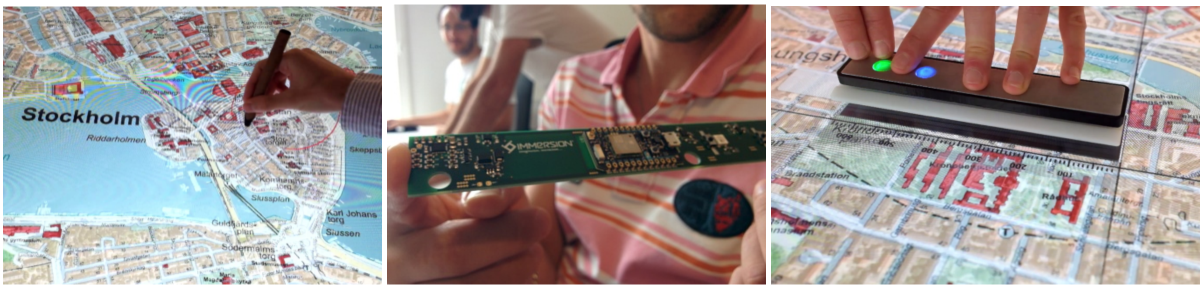

Figure 11. Design and prototype of tangible interfaces in order to replace the traditional tools

Our solution also enables tangible objects to interact with the system. By augmenting the capability of traditional objects, as ruler or pen, the project intends to engage the most resistant to the digital practices. By suggesting the capabilities of the digital environment and assessment tools manipulation with physical object, the novice forgets his apprehension and can immediately put forward his expertise.

Users can interact with a ruler and a pen on the digital map as a paper map. These tools, depicted in Figure 11, are indeed quite common for the preparation and assessment of building security: evaluate distances, add a point of interest, and define an area. Such functionalities have been identified by users as the absolute preconditions to federate a multi-profile group around a preparedness or management processes. Our tangible ruler has been designed from scratch with a dedicated Printed Circuit Board which communicates with the software and enables to switch between modes. The measure is furthermore facilitated by dynamically adapting the scale of the ruler to the zoom level on the digital map. By combining a tangible pen and a ruler, drawing digital lines becomes natural.

Collaborative Orchestration of Data

Our novel collaborative device also offers numerous functions to deal with improvisation work in inter-organizational group for operational usage. Such a functionality creates bridges with other information sources to consolidate any required information into the collective space and therefore facilitate the general acceptance of such an additional component. Indeed, according to (Ley, Pipek, Reuter and Wiedenhoefer, 2012), improvisation work suffers both from a lack of options for sharing information and a lack of collaboration resulting from consolidating and interpreting the information available. For that reason, our software was designed to support accessibility, aggregation and visualization of external and multiple-source information in mind.

In fact, aggregation of digital data on a horizontal display is critically different from what is required on a standard vertical screen. For instance, the difficulty in reading textual content from each side of the screen constitutes an important limitation during collaborative sessions. To this end, we developed a collaborative layer which enables users to open its own instance of a software program. All the programs instances run simultaneously on the same device, but the information is individualized for each user, such as the point of view (as illustrated in Figure 12). Annotations made with fingers or pencils can be synchronized on every related window in order to enhance the discussion driven by gestures on, for instance, a digital map. All the information aggregated in the collaborative view can be accessed and stored on any kind of mobile device (computer, tablet, smartphone).

Figure 12 – Aggregation of data enabling collaborative processes on a horizontal display

PERFORMANCES

The system has been designed to be fully interactive and provide real-time feedback. Commodity "gaming" computers, including laptops, are powerful enough to run our manual construction and assessment tools. The construction time of a facility can vary between a couple of minutes and a few hours, depending on the size and the complexity of the topology, i.e. the number of doors, windows, stairs and walls. The indoor capture system requires around a minute of capture per room. The processing time, i.e. transforming the captured images into a 2D footprint and 3D representation, is a few minutes for highly complex facilities. The creation of a security plan using the assessment tool takes a few seconds for each major virtual equipment, units and threats. From our experiments, most of the time spent by security experts during the assessment of a building was on discussions and not on technical manipulations. The assessment time of a building is thus raised by the leading considerations our solution fosters, which depends on the number of participants and the criticality of the asset.

SEEKING THE ADVICE OF END USERS

We demonstrated our Virtual Studio to a group of security professionals with different experience and backgrounds, including representatives from the police, fire services, military, government and a crisis consultancy organization. This was an opportunity to test and critically evaluate our research results.

The security users were split into two teams of eight people. Each team viewed a large screen showing a map with the 3D digital environment and representation (or "mock-up") of an existing embassy. The teams were asked to draw up a security plan for the embassy. They could, for example, add security fences, place barriers and road blocks, identify weaknesses in the building, view the building from different vantage points, and check the coverage area of specific security cameras. Having worked to strengthen security of the embassy building, the two groups were then asked to switch screens and assess the other team's security measures. Seeing the ideas of the other team sparked a new round of discussion, prompting the end users to reconsider ideas or develop new security concepts. Participants then explored critical features of the building itself, such as windows, emergency exits, the positioning of stairs, ducts, and cameras. They were then asked for their impressions.

Users agreed that our solution supports interdisciplinary collaboration among security professionals, in particular because it quite literally provides users with a shared picture of the building and its environment. This is achieved thanks to the 3D visualization of a replica of a building in the context of its accurate location on a map. It allows for an iterative process of designing security, testing security, and based on the results, improving security. Users stated that the system improves on their current processes, which are still largely paper-based. They appreciated that within one system, they could create plans and test security for various different threats or situations. Unlike their current practices, this solution also allows for saving, modifying and replaying past sessions, as well as storing and incorporating lessons learned.

Participants stated that being able to see not only a specific building, but the surrounding environment as well provides valuable situational awareness, allowing users to consider the building's proximity to other buildings, public areas, and transportation routes, in effect widening the focus to allow for an analysis of all necessary security aspects.

Specific key features of our solution were assessed during our experimentation:

1. While automated methods for capturing outdoor environments exist, standard approaches pay little attention to the acquisition of indoor scenes. Therefore all users really appreciated the capability to easily capture an indoor environment thanks to popular mobile devices such as smartphones, contrary to expensive devices such as laser scanners. This result was achieved without the need for a specific training, paying attention to the fact that the evaluators are not CAD experts or 3D modelers.
2. Users valued having an option to manually create a digital replica of a building in the event access to a specific building is not allowed or not feasible. Having learned how to 'draw' a building, they were satisfied with the tool and agreed that manually drawing and customizing buildings was easy to perform. Visualisation of a virtual replica of a building offers a safe environment in which security and many more threat situations can be more thoroughly assessed. Placing threats in the virtual environment allows users to better grasp the potential consequences of, for example, a fire blocking the evacuation route, a gunman with a hostage, or a group of violent protestors. Workshop participants observed our solution allows for thorough and cost-effective security assessments while also saving time and eliminating the need to travel to a specific location.
3. Flexibility in choosing viewpoints was also well-received. Users welcomed the possibility of hiding or viewing any combination of building features to see unobstructed views of areas of interest. One feature unanimously seen as innovative, of high value and unique to our proposition was the ability to clearly see the view and coverage areas from any vantage point, which users recognized as useful for placement of various types of personnel and equipment. Seeing the perspective of, for example, a sniper, security camera, police car or helicopter placed in the environment was a very welcome contribution difficult to achieve outside of a virtual environment.
4. Our collaborative hardware solution was designed to support interdisciplinary collaboration, and users agreed that this goal was achieved. When discussing security of the embassy building, various viewpoints of workshop participants were shared and incorporated, spurring ideas about how to ensure that the building was secure, but at the same time, assessable and able to be used for its intended purposes. Furthermore, users were particularly positive about the ability to change the table's orientation. Changing the table from a horizontal to a vertical position prompted discussions about additional uses, such as a presentation aid during response team's debriefing discussions. Participants noted that lessons learned could be visualised, then saved in the system for future related missions.

In addition to security design and planning purposes, participants highlighted the possible use in real time operations. Currently, arriving on scene, operational teams such as firemen and specialized police forces use pen and paper to draw rough 2D blueprints of buildings and highlight possible locations of targets or entrances. The 3D digital environment allows SWAT teams to see precise floorplans of buildings, both in 2D and 3D, offering a realistic and easily understandable view of the scene. Users can manipulate the view to move around the perimeter of the building, then remove walls, for example, or only show stairwells or doors. They can make annotations or use icons to show where a particular team should enter, or where suspects are thought to be located, for example. To receive critical information even sooner, task force participants were very interested in the transfer of data, in particular a screenshot of a building, including annotations, sent to their smartphones as they are on their way to a scene.

CONCLUSION

This paper has presented innovative IT tools that enable security professionals and administrators to jointly formulate, test, and adjust security concepts and measures in a virtual environment. The concept was borne out of a realization that the process of designing building security could be greatly improved. As urban environments continue to grow and are increasingly faced with evolving threats, the importance of interdisciplinary collaboration cannot be understated. During the system first and iterative evaluation, security-related professionals were enthusiastic about the novel solution's capabilities, agreeing that it offered advantages to their current methods of designing building security. Depending on their backgrounds, they focused on different features, discussing the benefits and offering suggestions for improvements.

Moreover, end users recognized the versatility of the system, sharing thoughts on how they could use it in various ways, including designing security, risk assessment, mission planning, (on-site) briefings for tactical teams, after action reports, offsite building assessment, and allocating security costs. End users showed interest in using this system at all levels, from the operational teams in the field, to specialized tactical response teams, to the strategic levels of crisis management. End users agreed that the added value resides in promoting interdisciplinary collaboration. It allows professionals to visualize the environment they are working to secure, enabling a more efficient and meaningful design and assessment of security measures.

Future work could increase its applicability to all phases of crisis management. Currently, the system seeks to improve security planning and the development of new security concepts. However, its use could be extended to training by adding features that include a time element, which would allow users to run scenarios. These scenarios could be more realistic by enabling the software to reflect real life conditions, for example, damage from a burning fire, or effects of precipitation or other weather-related factors. Furthermore, incorporating tools that allow for the live tracking of news and social media would make our research findings useful during crisis detection and response phases. Finally, future work could incorporate an analytics engine, allowing the system to search for weaknesses in the security design.

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